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TITLE: SPARK GAP OVERPRESSURES IN THE TRANSFER CAPACITOR DEVICE

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SPARK GAP OVERPRESSURES IN THE TRANSFER CAPACITOR DEVICE*

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A designer of spark gaps is often faced with two gas pressure problems, one static and one dynamic. The former is easy to obtain data on which to base intelligent design specifications; about the latter, less is known. It is the total internal pressure environment we have attempted to measure, in an un-time-resolved way, in order to give the designer some rationale in designing gaps of this category. We measure overpressures of ~ 400 PSI in a 13 cubic inch gap passing currents of ~ 200 kA.

A secondary reason for doing this work is that whenever a spark gap self-destructs, it often is difficult to determine, after the fact, whether an electrical failure preceded the mechanical breakdown, or whether mechanical failure led to the electrical trouble.

In order to measure the peak pressures in a spark gap we have applied the anvil-ball-sheet-of-lead method as the diagnostic. In ordnance work this arrangement is called a crusher gauge where such a device is used to measure the "g" forces of a propellant charge.[1] The spark gap under study was the transfer switch in the peaking capacitor circuit.[2] In terms of placement in the electric circuit, the spark gap is SW_3 in Fig. 1 (a schematic of an apparatus designed primarily for other studies).

Often thought of mostly as an electrical device, a spark gap is also a physical structure having properties and undergoing stresses that have not been studied, perhaps, in sufficient detail. One question always confronting the designer is: how much overpressure during the spark phase will the spark gap have to endure? The static pressure, often 50 to 60 PSI, is known and its effects calculable. (Actually the air pressure here controls the electrical breakdown voltage level of the spark gap; this static pressure does not really affect the crusher gauge.) In the field, the spark gap must withstand the static plus dynamic pressure generated during the firing of the spark gap; the dynamics are both less known and less calculable.

It had long been suspected that the overpressures encountered were high (based upon experience and intuition). Along with the magnitude of the pressure peak it would be even more instructive to measure the pressure's time history. Although the technology probably exists now in a form more sophisticated than the state of the art practiced by Blackstock[3] and others in 1964, we made no attempt--as a result of programmatic reasons--to measure pressure as a function of time. Here we recorded only the integrated pressure effect. The electrical impulse is short compared with the inertial response of the diagnostic system, which is drawn in Fig. 2.

Hot neutral gases impinge upon the exposed 0.037 sq. in. of the piston, which in turn moves the steel ball into the Pb disc. The diameter of the crater left in the Pb disc can, in turn, be compared with the craters caused by predetermined loadings. (Magnetic pressure, within the limits of the measurement, does not introduce an error.) Figure 3 shows the effect of applying known weights to the top of a 0.125" diameter ball; the diameter of the resulting crater is plotted as the ordinate.

For example, a 20 pound load made a crater in the Pb having a diameter of 0.060", as seen in Fig. 3. Figure 4 relates a 0.060" crater to an overpressure on the sensing piston amounting to 540 PSI.
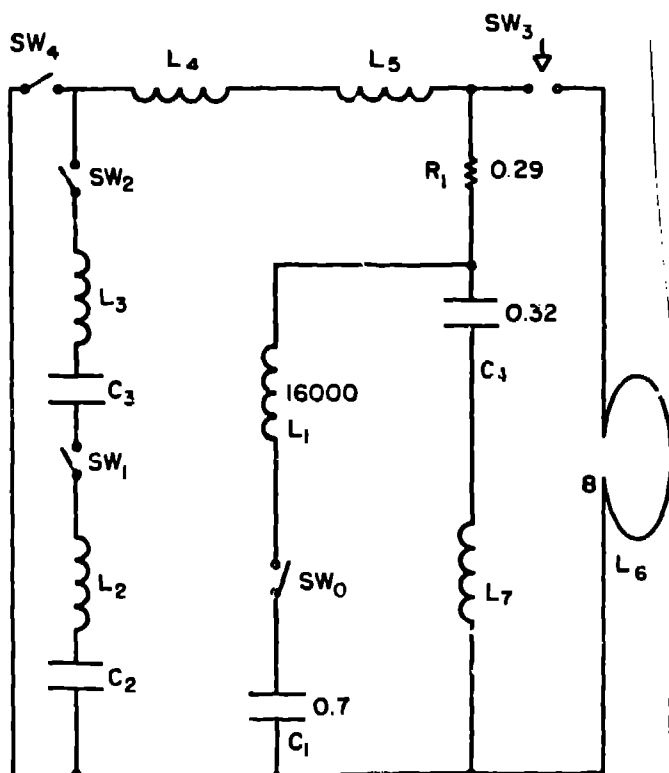

Fig. 1.
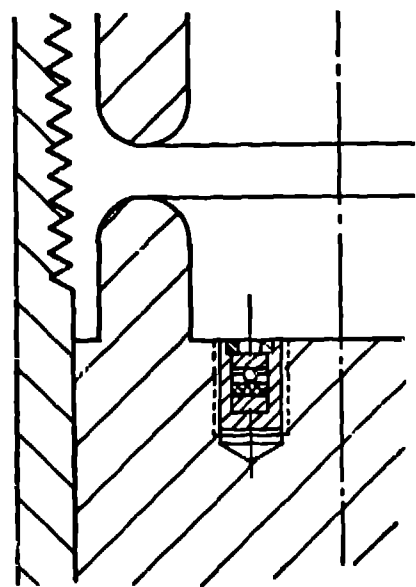Electrical schematic of experimental circuit; note SW_3 is gap under study.

Fig. 2 a.
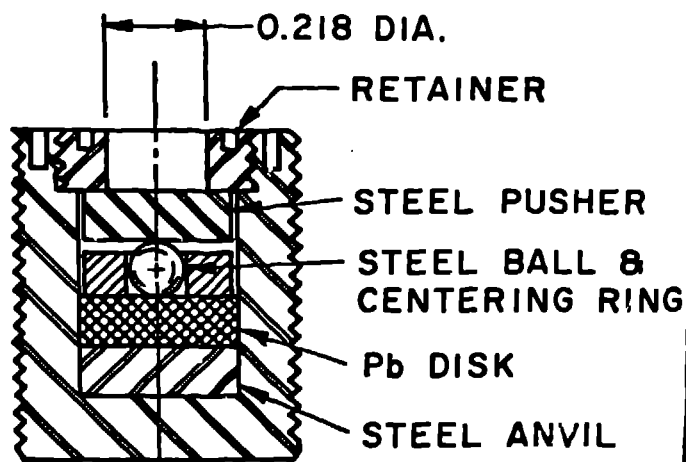Orientation of crusher gauge in the bottom of the gap.

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-0.218 DIA.
— RETAINER
— STEEL PUSHER
— STEEL BALL & CENTERING RING
— Pb DISK
— STEEL ANVIL

Fig. 2 b.
Mechanical details of crusher gauge.

Fig. 4.
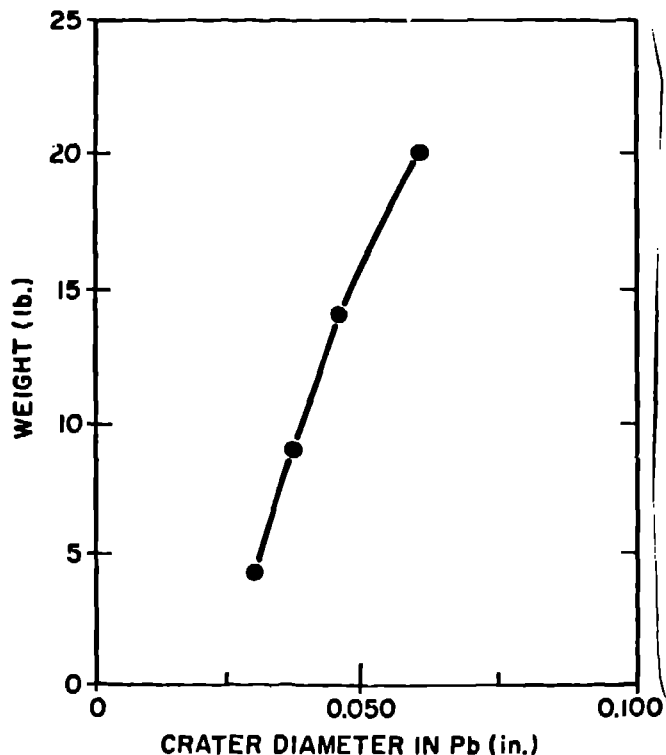Measured crater diameters as a function of gap current.

Fig. 3.
Calibration curve relating crater chamber to known weights.

Thus we obtain from the relationship

$$S = P/A = 20/0.037 \text{ sq. in.} = 540 \text{ PSI.}$$

Other values used were 14 pounds for 378 PSI, 9 pounds for 243 PSI, 4 pounds for 108 PSI etc, as examples. (The gap has a volume of - 13 cubic inches in which the trapped gases may expand.)
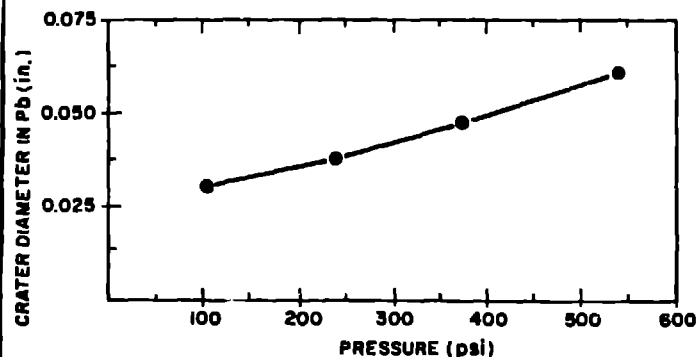
Having thus obtained a calibration, we installed an unblemished disc into the crusher gauge and fired the machine by discharging the electrical energy into an L-C ringing load through SW_3 under a variety of stored energies. Some typical electrical machine parameters are shown in Table I.

TABLE I

$V_{(Marxed)}$	85 kV
C_{mrx}	2.8 μF
C_{tr}	0.32 μF
Q_{mrx}	0.24
I	156 kA
τ	5 μs
decay (1/e)	- 20 μs

Table II shows the raw data.

TABLE II

KA	Diam mm	Diam Inches	Lb. Equiv.	PSI
86.6	0.80	0.0315	5	140
135.0	0.98	0.0385	7.5	260
200.2	1.25	0.0492	16	395

Figure 5 summarizes the overpressure's dependence upon the current transferred through SW_3; the typical error is an estimate. It would have been interesting to pursue this study to improve the statistics; however, space had to be made for the construction of ZT-40, a large reversed field pinch at LASL.

We conclude from these measurements on the spark gap that the overpressures are significant enough that proper account shall be made of such additional forces when designing constraint members whose function is to contain all the forces. This should be done strictly on a mechanical basis and without considering the postulated electrical causes of failure.
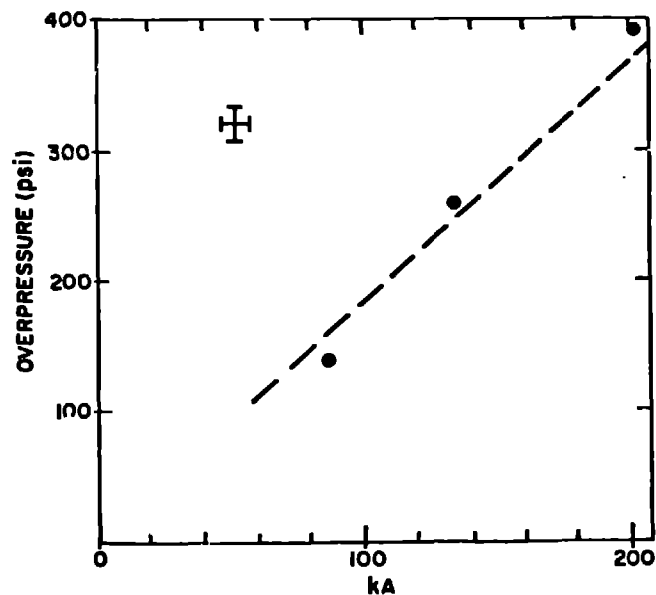
Acknowledgments

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Fig. 5.
Deduced gap overpressure as a function of gap electrical current.

References

1. _Elements of Ordnance_, prepared under the direction of Major General Thomas J. Hayes (John Wiley and Sons, Inc., New York, 1938), p. 92.

2. L. C. Burkhardt et al., "A High Voltage, High Current, Pulsed Energy Source Having dI/dt's of 2×10^{12} A/s," Proc. 6th Sym. on Engineering Problems of Fusion Research, San Diego, CA, 1975, p. 450.

3. A. W. Blackstock et al., Rev. Sci. Instr., Vol 35, No. 1, 105-110, January 1964.